7. SAFETY DISCUSSION

The AMS-02 Project has employed a methodical approach of for implementing a safe design for the AMS-02 payload. Safety has been a central focus of the Collaboration that has come together to create this international scientific instrument. With the evolution of the design of the AMS-02 since the Phase I Safety Review, held January 16, 2001, the design of the AMS-02 has undergone a renewed safety analysis to assure that all safety issues have been properly identified and addressed.

In the Phase I Safety Data Package (SDP) several systems were identified as being "re-flight" from the AMS (AMS-01) mission. Upon further review these systems were established to be sufficiently modified from the original flight design and configuration that they have now been directly addressed in the AMS-02 hazard analysis and hazard reports.

7.1 SAFETY ANALYSIS

The AMS-02 safety analysis considered the AMS-02 exterior elements and the interior elements that are to be utilized on the Shuttle Orbiter and the exterior elements to be berthed on the ISS. This analysis and SDP reflects the fact that the AMS-02 does not have any ISS interior elements.

The AMS-02 safety analysis and hazard reports generated consider the operations associated with the AMS-02 during the following operational phases:

- Pre-launch operations
- Launch and ascent
- On-orbit checkout of the AMS-02
- Shuttle RMS Operations
- ISS RMS Operations
- ISS PAS Installation
- ISS Operations

In addition the following contingency operations were considered in the safety analyses and hazard reports:

- Shuttle EVAs, past the AMS-02 and on Shuttle Program provided GFE (ROEU, FRGF)
- ISS EVAs past the AMS-02 and on ISS Program provided GFE (PVGF, PAS)
- AMS-02 Contingency EVA For Power Routing In-flight Maintenance (IFM)
- AMS-02 Contingency EVA For Data Routing IFM
- AMS-02 Contingency EVA For Manual Release of the PAS

7.1.1 Energy Analysis

The basic technique used to perform the safety analysis was identification of energy sources, energy transfer and energy concentration points in the AMS-02 design. This safety analysis technique utilizes the fact that in most cases, hazards cannot manifest without some form of energy existing and changing state or position. Energy can be categorized in a number of forms (generally), electricity, thermal, pressure, ionizing radiation, electromagnetic radiation, magnetic fields, chemical energy, kinetic, acoustic and organisms. By identifying these sources of energy and how they may be possibly transferred or concentrated, the fundamental hazards associated with AMS-02 have been identified.

7.1.2 Historical Comparative Analysis

In addition to the Energy Analysis technique for hazard analysis a complementary method of hazard analysis was utilized where a historical perspective of hazards addressed for payloads of the ISS and Shuttle was used to assure that there are no omissions in the AMS-02 hazard identification. This technique relied heavily on experiences of the safety and engineering community of the AMS-02 Project and an iterative approach to the design review and investigation.

7.1.3 Maintenance Hazard Assessment

The AMS-02 design does not require any regular maintenance procedures or conditional maintenance actions to be performed during the AMS-02 mission. A unique hazard analysis for maintenance operations has deemed to be unnecessary, all operations identified as nominal and contingency for the AMS-02 have been considered in the hazard analysis documented in this safety data package.

7.2 HAZARD REPORT GENERATION

The AMS-02 design was revisited with a renewed safety analysis in preparation of the Phase II Safety Data Package. As a result of the revised safety analysis the hazard reports were restructured and additional hazard reports added. To address this revision, new AMS-02 Project tracking identifiers were assigned to the hazard reports, differing from those used at the Phase I safety review. This difference is the addition of the "F" for flight in the number and a two digit numerical designator. With reorganization and additions of hazard reports, these designators may not correlate directly with previous hazard reports reviewed at Phase I. JSC Form 1230 has been used where possible to address Standard Hazards that satisfy the control and verification standards that are documented on the JSC 1230 Form. Two JSC Form 1230s have been prepared, one for AMS-02 exterior elements (Shuttle and ISS) and one for hardware that will be present within the Shuttle crew habitable environment. It was noted in the generation of the JSC Form 1230s for the AMS-02 phase II safety review that the JSC Form 1230 does not specifically address ISS Exterior Payloads, and in cases where it was clear the form was not able to address these payloads, a unique hazard report was generated.

AMS-02 hazard reports identified by the hazard analysis have been documented on a custom hazard report form that is compliant with the documented requirements of JSC/ISS 13830. The format of the hazard report groups controls and verifications together for direct correlation of the control and the associated safety verifications. Additionally a column that parallels the controls is present to identify all flight operational controls for quick reference. Character designators identify these controls, "I" for ISS based operation, and "S" for Shuttle based operations. Preflight ground operations are not identified in this column.

A consistent numbering convention has been applied to the hazard reports using the form "aa.bb.cc". In this format "aa" designates the Cause Number, "bb" the Control Number, and "cc" the safety verification method and status number. This methodology is maintained through the unique hazard reports, with the JSC Form 1230, the use of a slightly different numbering scheme utilizing the JSC Form 1230 letter designators required a minor deviation of the verification numbering methodology.

7.3 ACTION ITEM (AI) STATUS

The following actions were assigned at the AMS-02 Phase I Flight Safety Review held January 16, 2001.

Phase 0/I Action Items:

AI	Action	Date Due
1 Assigned to: SF3/J. Bates **(Now EA1/S, Porter)**	Continue to assess the helium venting analysis with Shuttle Integration and EP4 and develop a history of cryostat operations to determine the necessity of a Launch Commit Criteria (LCC) inside T-9 minutes to launch.	Date: Phase II Mandatory Reviewers: PSRP

Action item 1 was discussed in two special technical interchange meetings (TIMs) held with the PSRP on October 11 2001 and January 17, 2003. The monitoring of the Cryomagnet has been established to be an essential AMS-02 Verification Process and a Launch Commit Criteria has been established in hazard report AMS-02-F04, Overpressurization of Orbiter Payload Bay.

AI	Action	Date Due
2 Assigned to: SF3/J. Bates HR: AMS-02-6 **(Maps to Phase II HR AMS-02-F06)**	Pre-submit AMS-02 vent test data regarding TCS, warm helium supply, TRD, and the cryosystem to EP4/H. Flynn for approval; submit data to USA in April 2001 for analysis; and add results to HR AMS-02-6 for presentation at Phase II FSR.	Date: Phase II Mandatory Reviewers: PSRP

Action item 2 has been an ongoing effort to establish all possible venting rates and maximum volumes from all stored gas systems, exceeding the list of the action item. Special technical interchange meetings followed the Phase I safety review where the venting rates and thermal conductance that could lead to emergency venting of the superfluid helium as helium gas.

AI	Action	Date Due
3 Assigned to: NC55/S. Loyd HR: AMS-02-7 **(Maps to Phase II HR AMS-02-F07)**	Provide updates regarding changes to the magnetic requirements for the EMU and peripheral equipment, and status the relevant communication between the PO and EVA Project Office/XA. (PSRP may schedule a meeting with XA and AMS following review of the AI, if necessary.)	Date: February 18, 2001 Mandatory Reviewers:

This action item was closed at a special discussion meeting held by the PSRP on September 11, 2001.

7.4 AGREEMENTS

The following agreements were documented in the Phase 0/I minutes for the AMS-02 held January 16, 2001. Reference numbers to actions items are taken directly from the text of the minutes.

3.1 The Payload Organization (PO) agreed to accurately define the weight of the Xe transported in the Xe tanks in the TRD.

As documented in AMS-02-F04 the total quantity of xenon in the xenon tank of the TRD will be 109 lbs (49.54 kg).

3.2 The PO agreed to highlight or differentiate any new material in the Phase II SDP.

The Phase II Flight Safety Data Package has been substantially revised since the phase 0/I safety review, marking the new and updated material became impractical.

3.3 The PO agreed to research the rationale for the different requirements numbers from HQ, ISS, and AMS-02 personnel regarding MM&OD and *coordinate the findings with the Payload Safety Engineers (PSEs) assigned to AMS-02.*

The differences in the MM&OD requirements have been reviewed and presented to the Payload Safety Review Panel by NE2/D. Londa on December 5, 2003. In this presentation the proposal to change the NSTS 1700.7B ISS Addendum to include Probability of No Penetration from the current 0.9999 for 1 yr to be compatible with the SSP 52005C requirement of 0.9999 or 0.99999^(A*Y) whichever is lower (A – Area, Y – Years). A change request to make this change wax originated but at this time it has not become formally a part of NSTS 1700.7B ISS Addendum. AMS-02 is compatible with this desired requirement change as documented in letter KX-06-001, "Micro-Meteoroid Debris (MMOD) Requirements for the Alpha Magnetic Spectrometer (AMS)" dated February 17, 2006 from KX2/ISS MMOD Protection Subsystem Manager and NASA MMOD Protection Discipline Technical Warrant Holder. In this document the PNP value of 0.997 is documented as being justified based on the PSRP acceptance of the proposal to change NSTS 1700.7B ISS Addendum to be consistent with SSP 52005. AMS-02 is not generating a noncompliance to NSTS 1700.7B ISS Addendum as we feel we are in compliance with the intent of the safety community and MMOD community for MMOD control.

3.4 The PO agreed to highlight the Avionics Operations Profile for Phase II to designate that the information regarding the SFHe Tank Nominal Vent Valve opening during ascent and closing during a possible abort are only goals for mission success, not safety issues.

During ascent, a baroswitch and Orbiter computer based timer command to open a valve serves only to protect the Superfluid Helium supply from a wicking effect caused by liquid SFHe being in contact with a filter material. The unique capillary action of SFHe can result in the SFHe being drawn through the filter and released at an increased rate during <u>on-orbit</u> operations. By delaying the opening of this valve until the exterior pressure is approximately 5 mbar while vapor only is in contact with the filter plug, the SFHe is conserved and mission life is maintained. Mass flow rate during this condition is not sufficient to increase the overpressurization threat to the Orbiter, but does significantly affect the overall mission life of the AMS-02 if the flow rate is increased due to liquid "pumping" through the filter plug. This phenomenon is not a driving factor for Over-pressurization of the Shuttle Payload Bay causes and does not affect flight safety if the valve either does not operate or operates an inappropriate time.

3.5 The PO agreed to present information related to the ACOP drawer assembly Hard Drives when available, and to ensure that fans/filters are kept cleaned to provide clean cabin air.

The ACOP has been cancelled from the AMS-02 Project and will not be flown.

3.6 The PO agreed to define all TBDs in JSC Form 1230 for Standardized Hazards for Phase II.

The use of JSC Form 1230s have been substantially updated for the Phase II Safety Review for the AMS-02. There are no occurrences of TBD upon the form itself aside from closure dates which are represented as "open".

3.7 The PO agreed to add information to part "d" of Letter TAA-88-074, "Burst Disk Certification Approach," regarding materials and process control.

Excerpt from Space Cryomagnetics Memorandum 2484, "Burst Disc Qualification":

> It is not feasible to test burst discs for membrane actuation pressure. This requirement will instead be demonstrated through materials and process control. The burst disc manufacturer has been asked to advise SCL of the controls intended to be used. These will be passed on to ESCG/NASA for approval.

The control of the materials and processes of the burst disc manufacturer have been documented and reviewed for acceptability.

3.8 The PO agreed to add information to HR AMS-02-3 AMS-02 Pressure System-Cryomagnet table for Phase II.

All tables associated with the pressurized systems and structural elements have been substantially updated for phase II.

*3.9 NC44/(**Current PSE**) will verify that M. Golightly has a copy of the updated version of Form 44.*

A revised JSC Form 44 has been attached to AMS-02-F09 using the latest version of the form found on the JSC Payload Safety webpage as of the date of this document. The assigned NC44 PSE will have this form available to distribute to the appropriate technical representatives of the Space Radiation Working Group.

> *3.10 The PO agreed to coordinate with Cargo Integration after the research on the source data profile for time from launch vent profile is completed.*

AMS-02 project has worked with the Cargo Integration Office and their support personnel on the AMS-02 venting conditions. Boeing Technical Memorandum TS-TM-02-064, Alpha Magnetic Spectrometer II During Ascent and Descent Orbiter Operations, provides the acceptance of the AMS-02 design and analysis that demonstrates that the AMS-02 does not provide an uncontrolled risk to the Orbiter. The Cargo Integration Representative to the PSRP (JSC-MO2/S. Kunkle, 5/24/2005) has indicated that no further documentation beyond this memo will be generated.

The following agreements were generated at the Alpha Magnetic Spectrometer-02 Technical Interchange Meeting held on January 17, 2003:

> *3.1 The PO agreed to provide a thorough explanation of the continuous venting activity and characterization of the situation for the Phase II Review.*

AMS-02 project has worked with the Cargo Integration Office and their support personnel on the AMS-02 venting conditions. Boeing Technical Memorandum TS-TM-02-064, Alpha Magnetic Spectrometer II During Ascent and Descent Orbiter Operations, provides the acceptance of the AMS-02 design and analysis that demonstrates that the AMS-02 does not provide an uncontrolled risk to the Orbiter. The Cargo Integration Representative to the PSRP (JSC-MO2/S. Kunkle, 5/24/2005) has indicated that no further documentation beyond this memo will be generated.

> *3.2 The PO agreed to submit details of the lot screening program materials and process data for JSC Engineering review.*

The details of Cryosystem burst disk lot screening program and process data has been provided to JSC Engineering for review and concurrence. JSC Engineering has accepted the program and process and this is documented in hazard report AMS-02-F03.

7.5 HAZARD SUMMARY

The safety analysis of the AMS-02 has resulted in the generation of twenty integrated hazard reports and two unique JSC Form 1230 hazard compilation reports. Of the twenty integrated hazard reports, the previously deleted Phase I hazard report for Toxic Material Offgassing has been reopened for Phase II and although a complete nomenclature change has occurred with the hazard reports, the corresponding hazard report has been maintained with the same corresponding hazard report identifier (specifically AMS-02-2 at phase I and AMS-02-F02 for Phase II). Another hazard report has been withdrawn upon further investigation of the design and consequences of the potentially hazardous condition.

7.5.1 Structural Failure of Hardware

7.5.1.1 Structural Margin

The AMS-02 hardware to be launched in the Orbiter Payload Bay, transferred via SRMS and SSRMS to the ISS PAS location has been designed to maintain positive load factors for all required loading conditions. Hazard report AMS-02-F01 has been prepared to document the AMS-02 hardware's capability to safely complete the AMS-02 mission without losing structural margins, damaging the AMS-02, the Orbiter, the ISS or these vehicles' crew or the general public.

Structural safety of the hardware to be flown and used within the Orbiter habitable volume is addressed in hazard report STD-AMS-02-F01.

Fastener back-off, which is traditionally a concern of loss of structural load path or release of masses in excess of 0.25 pounds, has been addressed in STD-AMS-02-F01 with regards to the release of any fastener or mass as a result of fastener back-off. The release of a mass which can become a co-orbiting mass that can impact the ISS, the AMS-02 or other payloads has not been established to have a mass limitation, thus all fasteners have been shown to have the requisite back off prevent or be shown to be contained and not to release a mass with any possible back-off. Only in this latter condition, containment of any released mass, has the use of chemical thread lock been approved for use on the AMS-02.

7.5.1.2 Vented Volumes

The AMS-02 has been designed to have volumes that will equalize pressure during its mission. These volumes will either be shown to have adequate venting area for the enclosed volume or show adequate structural margin in the event that all vents are closed. This has been addressed in hazard report STD-AMS-02-F01.

7.5.1.3 Fracture Control

The AMS-02 structural components have been assessed for fracture control per the JSC Fracture Control plan. This is addressed in hazard report AMS-02-F01. (Pressure systems are also addressed for fracture control, and documented in hazard reports AMS-02-F03 and AMS-02-F05.)

7.5.2 Mechanism Failure

The AMS-02 makes use of two mechanical devices, both mandated by the ISS program, in its design. Both of these devices are addressed in hazard report AMS-02-F11.

7.5.2.1 EVA PAS Release Mechanism

The EVA releasable PAS requires an excess of three failures to occur to inadvertently release the preload of the ISS PAS grapple system and allow for the withdrawal of the capture bar. The requirement for operability of the EVA releasable PAS capture bar only requires that the system be zero fault tolerant (SSP 57021, Section 4.1.2.2.1) to add the last required means of clearing a payloads from the ISS truss.

7.5.2.2 ROEU Bracket Folding Mechanism

The ROEU Bracket folding mechanism is an ISS program requested mechanism to provide additional clearance between the AMS-02 and the adjacent payload envelop.

Originally the AMS-02 had an agreement with the ISS Program that this volume would not be used and AMS-02's protrusion from the payload envelope was acceptable. A MAGIK analysis of the AMS-02 and a worst case berthing of an adjacent payload, such as an EXPRESS Pallet, showed a minimum clearance of 1.5 inches considering stacked misalignments. The folding mechanism for the ROEU Bracket will allow for a greater margin to exist, although it does still extend outside of the nominal payload envelope designated in SSP 57003, Section 3.1.3.1.1.1. The exceedences of the AMS-02 with the payload envelope, considering the folding of the ROEU Bracket, are accepted in the AMS-02 ICD by waiver. As the MAGIK analysis does not indicate a collision is possible, and the mechanism will only be considered to be operated in the event of a manifesting change that is currently undocumented, this mechanism is not considered safety critical for a must work situation.

Once operated, the ROEU Bracket folding mechanism will need to restrain the motion of the hinged bracket. While there is little concern that structurally this will survive loads, providing this condition, with an unknown number of rotational impacts is not feasible. Thus at least a single securing EVA pip pin will be required, to keep the Bracket restrained.

7.5.2.3 Unable to Berth, Collision

The AMS-02 utilizes the shuttle and ISS robotic arms for maneuvering to berthing locations in the Orbiter (for a contingency return) and on the ISS (for nominal berthing for mission.) The AMS-02 has installed grapple fixtures in appropriate locations to meet the center of gravity requirements and other ICD requirements, for robotic handling and will provide accurate models of the entire AMS-02 for the robotic motion analysis and simulators. The AMS-02 is entirely passive with regards to berthing operations, with the exception that it has integrated into its structure and avionics the Electronic Berthing Camera System (EBCS). The EBCS has been installed according to the ICD and will have its critical alignment verified prior to launch. The mounting of the grapple fixtures and installation of the EBCS have been addressed in hazard report AMS-02-F11, Mechanical Failure.

7.5.3 Rotating Equipment

The AMS-02 makes use of pumps within three of the systems that comprise the payload: Cryosystem, TRD and TTCS. The Cryocooler does not utilize rotating equipment as it is a reciprocating pump. Thermo-mechanical pumps utilize a thermal property of Superfluid Helium to draw the liquid through a membrane by heat alone, thus contains no moving parts. All applications or rotating pumps are considered to be low energy and contained in the event of a dissolution of the rotating elements. This is documented in hazard report STD-AMS-02-F01.

7.5.4 Pressurized Systems

The AMS-02 utilizes a number of pressurized systems in accomplishing its function. These systems are addressed in a number of hazard reports. The rupture of the pressurized systems have been addressed in two hazard reports, AMS-02-F03 for the Cryomagnet System and the Vacuum Case and AMS-02-F05 for the other pressurized or fluid containing systems on the AMS-02. The hazard of over-pressurization of the Orbiter Payload Bay has been addressed in hazard report AMS-02-F04, addressing the source potential of all fluids and the nature of the worst case evolution of helium from the cryogenic supply of superfluid helium.

7.5.5 Excessive Thrust/Overturning Moments

The AMS-02 has identified the potential for the AMS-02 to generate forces that could affect robotic operations and vehicle stability. The presence of high pressure gaseous systems and the generation of an intense magnetic field are direct potential causes for this condition.

All pressure system vents will either be capped or provided with zero-thrust vent caps that will minimize the potential for generation of resulting forces. The AMS-02 magnetic field is designed to have a minimum exterior effect in generating a torque that is perceivable to the ISS. These potential hazards and controls are addressed in hazard report AMS-02-F06.

7.5.6 Radiation

The AMS-02 has systems that can generate radiation and strong field effects that are essential for the experiment objectives. These are addressed in the following paragraphs.

7.5.6.1 Excessive Radiated Field Strengths, EMI

The AMS-02 will be complying with both Orbiter and ISS EMI/EMC requirements, compliance is documented in hazard report AMS-02-F07.

7.5.6.2 Magnetic Fields

The AMS-02 makes use of an intense magnetic field within the bore of the instrument. The exterior fields have been designed to minimize the field as much as possible. The EMU and standard EVA tools have been certified through a cooperative effort to show good for the maximum fields they could see why translating past the AMS-02. In the event an EVA to the AMS-02 is required, the magnetic field will be dispersed and prevented from being reformed until after the EVA operations at the AMS-02 are complete. This hazard is addressed in detail in hazard report AMS-02-F07.

7.5.6.3 High Intensity Light

The hazards from visible, infrared and ultraviolet electromagnetic energy have been established in the AMS-02 hazard analysis to have two possible sources, from an internal AMS-02 source and from an external source that is redirected. The internal source identified for AMS-02 comprises the ten laser diodes used to check the alignment of the AMS-02 Tracker and the external source the sun reflecting off of the AMS-02 thermal control features.

7.5.6.4 Exposure to Coherent Light (Lasers)

The only source of coherent light generated by lasers is within the Tracker Alignment System (TAS). The application of laser diodes within the TAS is documented in unique hazard report AMS-02-F20. The Class IIIb laser source is contained within the source boxes and transmitted to the interior of the Tracker by fiber optic cables. The laser beam path is entirely closed from the light tight source boxes (LFCR) to the light tight tracker assembly. Even if the fibers carrying the laser illumination should be able to freely radiate, the laser power has been reduced by optical splitting of the beam into multiple fibers (individually sheathed and connected) to have a non-hazard zone (NHZ) of 2.4 cm. AMS-02-F20 is classified as catastrophic as the laser diodes are capable of emitting 80 mW at 1083 nm which could conceivably create permanent damage to human tissue and eyes. AMS-02-F20 demonstrates energy containment and design compliance with ANSI-Z 136.1.

7.5.6.5 Excessive Glare

Hazard report AMS-02-F19 was established to document the potential hazards identified in the hazard analysis associated with a highly reflective payload redirecting solar illumination. The AMS-02 utilizes a number of highly reflective thermal control devices including silver coated Teflon tape. The concern that these reflective surfaces could affect EVA operations, camera viewing and ISS based observations could result in the use of contingency operations warranted looking at this condition as a hazard. Further research into the concern among the ISS and EVA communities placed this not in an arena of contingency operations, making it critical hazard, but mission planning and for EVAs, such as the requirement of use of the visor if there is a glare situation. This hazard report has been withdrawn based on this information and the fact that the AMS-02 design in no way concentrates sunlight, only disperses it. The issue of thermal heat loads to adjacent payloads cause by the reflective surfaces is addressed not as a safety issue but as an environmental issue within the ISS attached payloads integration process and addressed thoroughly there. AMS-02-F19 has been withdrawn as an active hazard and this hazard report ID has been set aside and will not be used for a different hazard potential.

7.5.6.6 Exposure of the Crew to Excessive Ionizing Radiation

The AMS-02 utilizes iron citrate (Fe^{55}) as a calibration source for the TRD gas supply. This iron citrate is deposited (bonded chemically) to the interior of the four calibration tubes within the Monitor Tube. The thickness of the Monitor Tube is sufficient to eliminate any radiation penetration. Through the evolution of the Monitor Tube, it has been referred to in documentation as Calibration Tubes and Proportional Tubes.

During AMS-02 ground testing, the science instruments will be subjected to controlled particle beams. These particle beams will validate the science instrument operations. While this beam qualifies as a radioactive source, it can not induce residual radioactivity in the materials of construction of the AMS-02.

Exposure to radioactive materials and ionizing radiation is address in hazard report AMS-02-F09, "Exposure of the Crew to Excessive Ionizing Radiation."

7.5.7 EVA Operations Hazard

AMS-02 has been designed to be compatible with a number of contingency EVAs associated with the GFE used on the AMS-02. There are also three EVAs associated with contingency operations with AMS-02 hardware. These include the EVA rerouting of power and data cables for ISS bus connectivity, folding of the ROEU bracket to provide additional clearance for the adjacent payload, and the ISS required alternate means of releasing the AMS-02 from the PAS location. EVA compatibility issues have been addressed in hazard report AMS-02-F14. Hazards addressed in this hazard report include thermal extremes, sharp edges and corners, stored energy release, and electrical shock.

7.5.8 High Voltages

The AMS-02 utilized a number of voltages in excess of 32 volts direct current (Vdc). The AMS-02 utilizes protection techniques, appropriate selection of cabling and grounding to preclude hazards of electrical shock, discharge and corona. These hazards are addressed in hazard report AMS-02-F08.

7.5.8.1 Electric Shock/Discharge

The AMS-02 utilizes the ISS provided 120 VDC and converts that power to a number of different voltages, some of them exceeding 1000 VDC. Hazard Report AMS-02-F08 has been developed to document this catastrophic level hazard. The controls documented in

AMS-02-F08 focus on the high voltage sources and loads and the compliance with high voltage wiring, connections, potting and grounding requirements. The primary control for exposure of EVA crew to electrical shock is the discharge of the stored energy of the magnet prior to the EVA, cessation of power application prior to an EVA and UPS battery circuit design that isolates continuously powered elements from EVA sites.

7.5.8.2 Coronal Discharge

As the AMS-02 utilizes high voltage sources and can release readily ionizable gases in the course of operations (principally from the TRD system) the AMS-02 has implemented high voltage insulation and potting protocols to limit the coronal discharge potential. AMS-02-F08 documents the techniques used to limit coronal discharge potential. Extensive testing of AMS-02 circuits and loads has shown that coronal initiation voltages for these designs are not met and the AMS-02 design. The actual coronal discharge could damage AMS-02 hardware through degradation and generate a "white noise" EMI, but there is no damage potential to the ISS directly from any conceivable coronal discharge with AMS-02 hardware.

7.5.9 Electrical Power Distribution Damage

The AMS-02 design protects the vehicle's power supplies and its own internal wiring from damage due to excessive load. This is addressed in hazard report AMS-02-F17.

7.5.10 Mate/De-mate of Connectors

Nominal operations of the AMS-02 do not require the connection of any cable with the exception of the communications cable connecting the PGSC interface card to the OIU. The AMS-02 does however have a number of contingency operations that it must support, Shuttle, ISS and its own where the de-mating and mating of connectors will occur. The mating and de-mating of connectors, by EVA, is addressed in hazard report AMS-02-F12.

7.5.11 Battery Failure

The AMS-02 utilizes a battery system to provide for Cryomagnet protection in the event of AMS-02 power loss. This battery system is addressed in hazard report AMS-02-F13.

7.5.12 Ignition of Flammable Atmospheres

The AMS-02 has a minimum of powered systems during ascent. These include the UPS battery system and the ascent valve system that is used to manage the proper flow of helium gas out of the Dewar without inducing an unacceptable loss rate (for mission success, this is not safety related). During ascent a baroswitch will make a valve open late in the ascent phase. These electronics and electrical components will be shown not to be able to ignite a flammable atmosphere in hazard report STD-AMS-02-F01

7.5.13 Flammable Materials

The hazard of fire, controlled by the use of materials which are non-flammable or possibly flammable but protected from being a significant threat, is addressed for the crew habitable volume of the Orbiter in hazard report STD-AMS-02-F02. The materials of construction of the AMS-02, the elements in the Orbiter Payload Bay, are addressed in hazard report AMS-02-F10. The AMS-02 also makes use of working fluids in the thermal control systems that can be flammable. These gaseous/liquids are addressed in hazard report AMS-02-F10.

7.5.14 Shatterable Material Release

The AMS-02 makes extensive use of photomultiplier tubes and frangible materials in order to accomplish its science objectives. Hazard report AMS-02-F16 addresses each of these sources and how the materials are either contained or qualified not to break during the AMS-02 mission.

7.5.15 Toxic Material Release

AMS-02 will have hardware within the Orbiter habitable volume, these items will be assessed for off-gassing compliance. Compliance is addressed in hazard report AMS-02-

F02. The AMS-02 does not make use of other chemicals within the crew habitable environment that could have a toxicological effect.

7.5.16 Thermal Extremes

The use of cryogenic fluids creates a condition where the AMS-02 can be the source of an extreme cold. The design of the AMS-02 limits this exposure and is addressed in AMS-02-F15.

7.5.17 Rapid Safing/Payload Reconfiguration

The AMS-02 has a limited number of configurations that it can be placed in physically. Hazard report AMS-02-F18 addresses the AMS-02 operations and configurations and how they do not affect the ability of the AMS-02 to safety return in the Orbiter or handle ISS loads.

7.6 FIRE DETECTION AND SUPPRESSION SUMMARY

The AMS-02 does not include any hardware that will be operated within the ISS habitable volume. No Fire Detection and Suppression design features are required for the AMS-02.

7.7 OPERATIONAL CONTROLS

The prepared unique hazard reports for the AMS-02 has an additional data element beyond those required by NSTS/ISS 13830 for the content of payload safety hazard reports. This additional data element is a column that indicates the use of operational controls. A control that uses an operational control has a designator in this column, an “S” for a shuttle based operation and “I” for ISS based operation.

A reference list of all these designations is provided in Table 7.7-1.

TABLE 7.7-1 OPERATIONAL PROCEDURE CONTROLS

Hazard Report	Control	I/S	Summary
AMS-02-F06	4.2	I	Discharge stored energy/magnetic field of AMS-02 prior to any removal (robotic) from ISS berthing location.
AMS-02-F07	1.3	I	Discharge stored energy/magnetic field of AMS-02 prior to any removal (robotic) from ISS berthing location.
AMS-02-F07	1.6	I	Discharge stored energy/magnetic field of the AMS-02 prior to any EVA procedure to be conducted on or with the AMS-02.
AMS-02-F07	1.6	I	Keepout zone (warning) for EVA when magnet is charged.
AMS-02-F07	1.7	I	SSRMS handling of AMS-02 to assure that primary power feed is used when handling the AMS-02 to assure that power feed capable of charging AMS-02 magnet is not engaged.
AMS-02-F07	3.3	I	Discharge stored energy/magnetic field of AMS-02 prior to any removal (robotic) from ISS berthing location.
AMS-02-F08	1.1	S	Procedural controls to remove power to the AMS-02 before any EVA access while on the Shuttle.
AMS-02-F08	1.1	I	Procedural controls to discharge magnetic field and removal of power to the AMS-02 prior to EVA Access of the AMS-02 on the ISS. (Power removal recommended to occur late in EVA process for thermal conditioning.)
AMS-02-F08	2.6	S	Prior to ROEU to ROEU-PDA de-mate, power will be removed from connection and remain off once de-mated.
AMS-02-F08	3.1	S	Review of crew procedures for contingency return of AMS-02 to assure that high voltage supplied to the AMS-02 from the Orbiter is turned off prior to entry.
AMS-02-F12	1.1	I	Procedural controls calling for the removal of power to the AMS-02 prior to EVA Access of the AMS-02 on the ISS. (Power removal recommended to occur late in EVA process for thermal conditioning.)
AMS-02-F14	3.1	I, S	Identify the sharp edge keep away zone of the Star Tracker optical baffle.

Hazard Report	Control	I/S	Summary
AMS-02-F14	5.2	I	EVA procedures to establish correct process to release stored energy of the AMS-02 to PAS interface and remove the AMS-02 from the PAS.
AMS-02-F14	6.2	I	EVA procedures to call for the use of the EVA power tool to avoid excessive repetitive cycles for release of the AMS-02 from PAS by EVA technique.

A launch commit criteria exists for the AMS-02 that related directly to the AMS-02.

> During pre-launch activities, the status of the superfluid helium tank will be monitored for signs of loss of thermal isolation (vacuum case breach/leak). In the event that there is an increase in pressure indicating the loss of thermal isolation, launch will be scrubbed. Monitoring will continue at a minimum to within L-9 minutes. Credible loss of thermal isolation at L-9 minutes can not manifest to an over-pressurization of the Orbiter payload bay hazard in the time available.

The AMS-02 controls reflect the use of three flight rules.

Hazard Report	Control	I, S	Flight Rule Summary
AMS-02-F07	1.3	I	The SSRMS will not grapple the AMS-02 until the AMS-02 has discharge the magnetic field either through command or operation of the "watchdog timer".
AMS-02-F11	1.3	S	Four of four PRLAs and active keel latch must be secured to return with the AMS-02 installed in the Orbiter payload bay.
AMS-02-F18	1.5	S	Four of four PRLAs and active keel latch must be secured to return with the AMS-02 installed in the Orbiter payload bay.

7.8 FLIGHT SAFETY NONCOMPLIANCES

The AMS-02 Project has not identified any noncompliance to NSTS 1700.7B or NSTS 1700.7B ISS Addendum. No noncompliance reports have been generated for the AMS-02 payload.

The AMS-02 is proceeding with their design based on the PSRP's documented intent to alter the requirements of NSTS 1700.7B ISS Addendum section 208.4e to change the requirement of a Probability of No Penetration from 0.9999 to the requirement documented in a change request to NSTS 1700.7B ISS Addendum that would make the value for PNP consistent with SSP 52005. To that end the AMS-02 has been design for it's original mission life and area of PNP concern to yield a value of PNP=0.997. This is documented in letter KX-06-001, "Micro-Meteoroid Debris (MMOD) Requirements for the Alpha Magnetic Spectrometer (AMS)" dated February 17, 2006 from KX2/ISS MMOD Protection Subsystem Manager and NASA MMOD Protection Discipline Technical Warrant Holder. While the AMS-02 is not currently in compliance with the current version of NSTS 1700.7B ISS Addendum, AMS-02 has not generated a non-compliance in anticipation of the implementation of the CR into NSTS 1700.7B ISS Addendum.

7.9 HAZARD REPORT LIST

Table 7.9-1 provides a listing of all AMS-02 hazard reports with title and current Phase II status. Phase I status is not provided due to the restructuring and new numbering nomenclature used in the development of the Phase II SDP. All hazard reports presented at Phase I were approved with modifications at that time.

TABLE 7.9-1 AMS-02 HAZARD REPORT LIST

HR ID	Hazard Report Title	Phase II Status
STD-AMS-02-F01	Flight Payload Standard Hazard Report – Exterior Elements	Open
STD-AMS-02-F02	Flight Payload Standard Hazard Report – Interior Elements	Open
AMS-02-F01	Structural Failure of Hardware	Open
AMS-02-F02	Toxic Material Off-gassing	Open
AMS-02-F03	Rupture of Superfluid Helium Tank, Vacuum Case and/or Pressurized System	Open
AMS-02-F04	Over-pressurization of Payload Bay	Open
AMS-02-F05	Rupture of AMS-02 Pressurized Systems: TRD Gas System (Xe & CO_2), Cryomagnet Warm Helium Gas System, Tracker Thermal Control System, Thermal	Open

HR ID	Hazard Report Title	Phase II Status
	Control System, Cryocooler	
AMS-02-F06	Excessive Thrust/Overturning Moments	Open
AMS-02-F07	Excessive Radiated Field Strengths, EMI, Magnetic	Open
AMS-02-F08	Electric Shock/Discharge	Open
AMS-02-F09	Exposure of the Crew to Excessive Ionizing Radiation	Open
AMS-02-F10	Flammable Materials in the Payload Bay	Open
AMS-02-F11	Mechanism Failure	Open
AMS-02-F12	Mate/De-mate of Connectors	Open
AMS-02-F13	Battery Failure	Open
AMS-02-F14	EVA Operations Hazard	Open
AMS-02-F15	Thermal Extremes	Open
AMS-02-F16	Shatterable Material Release	Open
AMS-02-F17	Electrical Power Distribution Damage	Open
AMS-02-F18	Rapid Safing/Payload Reconfiguration	Open
AMS-02-F19	Excessive Glare	Withdrawn
AMS-02-F20	Crew Exposure to Coherent Light	Open